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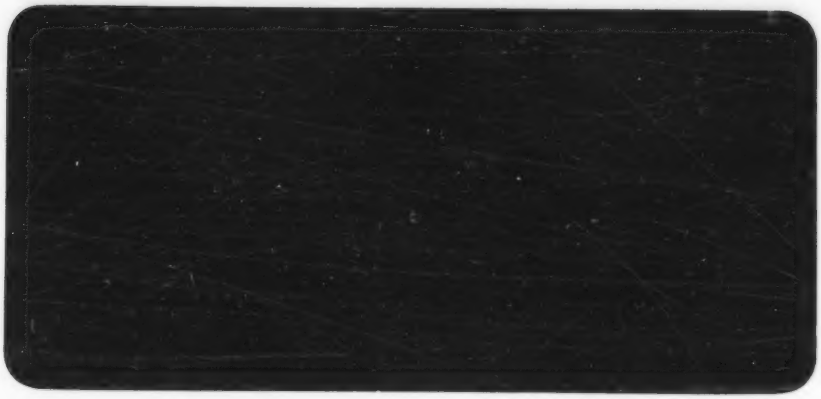

Department of Finance

Fiscal Policy and Economic Analysis Branch

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Are New-Classical Models Becoming Relevant Policy Tools: A Survey of Recent New-Classical Models

by

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ABSTRACT

Although the early work on Real Business Cycles (RBC), due to Kydland and Prescott (1982) and Long and Plosser (1983), had no role for fiscal or monetary policy, the recent new-classical research agenda over the past ten years has come closer to being a practical tool for public policy. This paper surveys the original RBC model, as well as its recent extensions. Specifically, the paper explores the relevance of new-classical models in dealing with observed real economic problems once these models are modified to include money, a role for fiscal policy, as well as when the economy is open. This paper also focuses on recent research by Lucas, King and others in introducing nominal rigidities into the new-classical framework, and concludes that this stream of research holds considerable promise for making new-classical models a viable and practical tool for the study of public policy.

RÉSUMÉ

Bien qu'il n'y eût aucun rôle pour la politique fiscale et monétaire dans les modèles originaux de cycles d'affaire réels (Kydland et Prescott (1982) et Long et Plosser (1983)), les recherches nouveau-classique des dix dernières années sont venues près de rendre ce type de modèle un outil pratique pour l'analyse des politiques. Ce travail revoit le modèle original des cycles d'affaire réels, ainsi que ses différentes extensions. Ce travail examine aussi l'utilité des modèles nouveau-classique dans l'étude de sujets pratiques, tels que l'impact de la politique fiscale, les questions touchant l'économie ouverte et la présence de rigidités nominales comme l'ont soulevée Lucas, King et biens d'autres dans leurs travaux préliminaires. Ce travail conclut que, grâce aux recherches actuelles, l'avenir des modèles nouveau-classique, comme outil pour l'analyse des politiques, est très prometteur.

1. Introduction

During the 1960s, large macroeconometric models based on Keynesian ideas performed relatively well in explaining the observed movements in economic variables. As such, the Keynesian paradigm provided policy makers with rules for fiscal and monetary policies. A key policy issue faced by the policy maker was to find a desirable location on the Phillips curve. Although the Keynesian model was originally developed to deal with observed fluctuations in economic activity that could not be explained by the classical model, the advent of supply-side shocks in the early 1970s began to cast doubt on the performance of the Keynesian class of models. The diminishing ability to closely match observed phenomena, coupled with a lack of microeconomic foundations for the aggregate relationships featured in these macroeconomic models, made them susceptible to increasing amount of criticism from academic economists and policy advisors. Although these models were quite large (comprising well over 200 equations), they featured static relationships between aggregate variables, and although dynamic equations in the form of behavioral rules were later introduced, these again were not based on microeconomic foundations. There were many attempts to improve the qualitative and quantitative performance of the Keynesian paradigm, the most notable of which were efforts to find microeconomic foundations within the Keynesian system, and the inclusion of sophisticated supply-side dynamics into the Keynesian framework.

Others, however, who viewed the problems with the Keynesian framework as fundamental, returned to a classical framework of microeconomic-based theory to explain aggregate fluctuations. To that end, the work of the new-classical economists in the early 1970s provided an alternative framework for the evaluation of the business cycle. The first dynamic general equilibrium model for the study of the business cycle appeared in 1972 by Robert E. Lucas. In this framework, aggregate fluctuations are explained by individuals with rational expectations who maximize their welfare based on signals they extract from the economy. In this economy, Lucas's monetary-misperceptions model was based on individuals arriving at sub-optimal equilibria due to the presence of noise in the prices that firms and individuals use to arrive at production and consumption decisions. A noise in prices stemming from random monetary shocks could partially obscure the important distinction between relative and general price increases in the economy. Unfortunately, although these models were internally consistent (that is, they were based on households' and firms' micro-economic optimizing decisions), they

did not fare well empirically. In the late 1970s, policy makers had to choose between internally consistent models that did not match observed phenomena and more empirically successful models that were not internally consistent.

In the early 1980s, work by Kydland and Prescott (1982) and Long and Plosser (1983) initiated a new paradigm for the analysis of business cycles. This stream of research, known as the real business cycle (RBC) approach, has achieved much success over a relatively short time span, and has become a competing paradigm for the explanation of business cycles among academics. RBC methodology relies on constructing a relatively simple stochastic dynamic general equilibrium model where the *propagation* of shocks is given much attention. In the RBC framework, the sources of the shocks to the economy are real - often technology shocks, or alternatively, taste shocks - but it is the optimal response of households in the economy that explains movements in consumption, hours worked and output. Households are assumed to choose consumption and hours worked in order to maximize lifetime utility. The initial RBC models did not include a role for fiscal or monetary policies, contrasting sharply with Lucas' monetary-misperceptions model that emphasized the role of monetary policy in causing business cycles, and which provided the general framework that initiated the RBC agenda. Yet, although the RBC models did not explicitly include money, the propagation mechanism remained consistent with the money-misperceptions framework. Furthermore, this propagation mechanism could also be loosely consistent with nominal price and wage stickiness models.

The abstraction of the original RBC models from monetary policy did not necessarily imply that money had no role. Rather, the view was that monetary policy played a minor role compared to technological shocks in trying to explain aggregate fluctuations, and reflected an attempt to model the behaviour of aggregate variables in general equilibrium without resorting to nominal rigidities. More recent developments in the stream of new-classical research have, however, extended the original RBC work to include nominal variables and thus, strictly, should no longer be classified as RBC. By incorporating fiscal and monetary policies into their analysis, these stochastic general equilibrium models have moved closer to becoming a viable and credible tool for the analysis of public policy.

Perhaps the most striking feature of the Keynesian approach is the slow adjustment of prices in the economic system. In this paradigm, some markets do not clear and output reacts

through a process of multipliers due to lags in the adjustment of prices. More recent advances by Phelps (1994) feature efficiency wages as a means of modelling sluggish wage adjustment. In contrast, new-classical models have assumed that prices adjust instantaneously to clear all markets. New-classical models therefore feature intrinsically different policy transmission mechanisms. However, although new-classical models have been exclusively associated with the flexible prices feature of the Walrasian framework, recent new-classical models have begun to incorporate sluggish price and nominal wage adjustment into the new-classical consumer-maximizing framework.

Ten years ago, the debate in macroeconomics revolved around two "second-best" solutions: a Keynesian approach that fitted the data but lacked internal consistency, and a microfoundations-based RBC approach that had a very mixed ability to fit the data. Reflecting this, macroeconomics has split into two streams: first, a new-Keynesian approach that seeks to provide rigorous microfoundations for price rigidities, and second, a continuing attempt to improve the fit of the new-classical models. The solutions, however, remain second-best. New-Keynesian models are partial equilibrium in nature - a general equilibrium framework featuring microfoundations-based price rigidities has yet to built - while new-classical models, although improved, still fail to explain some important business cycle facts. This paper is intended as a guide to new-classical general equilibrium models, discussing their features and properties, as well as describing where they appear to be headed. It will be apparent that the new-Keynesian and new-classical research agendas are to some degree converging, with some new-classical researchers incorporating new-Keynesian features in their models. Such models feature a marriage of optimizing agents and imposed price rigidities. While these too remain a second-best solution, they are likely a step beyond pure RBC models, and the older *ad hoc* Keynesian models.

This survey reviews seminal models representative of the new-classical research agenda[1]. Section 2 describes the original RBC model, while section 3 surveys more recent work that incorporates money and government. Section 4 examines open economy models, and section 5 surveys new-classical models with nominal rigidities. Section 6 offers conclusions.

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[1] The reader can refer to other surveys of RBC models, such as McCallum (1989), and Stadler (1994) for further discussion of the topic.

2. A Basic Real Business Cycle Model

In attempting to understand the workings of the new-classical dynamic general equilibrium models, it is useful to begin with the a basic real business cycle model. Although this model does not by itself provide much policy relevance, it does develop a useful dynamic optimization strategy. It should be kept in mind that although the simple model explored in this section has an analytical solution due to simplifying assumptions on preferences, technology and depreciation, most RBC models are more sophisticated derivations that do not have analytical solutions and are solved using numerical approximations.

2.1 A description of the model

Let there be a large number of identical households populating an economy. At time t these households seek to maximize utility over their future. Each household then maximizes

$$E_t[\Sigma_{j=0}^{\infty} \beta^j \, u(c_{t+j}, l_{t+j})] \tag{2.1}$$

where c denotes consumption; l denotes labour; β is a discount factor bounded by zero and one; E_t is an expectations operator at time t; and u is a well behaved utility function (i.e. $u_i>0$, $u_{ii}<0$) satisfying the Inada conditions[2]. Leisure in this model is measured as time spent away from work. Assuming that the households' total time endowment is normalized to 1, leisure can be written as $l_t=1-n_t$, where n_t is the labour supplied by the household.

Production in the economy is assumed to be represented by

$$y_t = z_t f(n_t, k_t) \tag{2.2}$$

where y_t is the economy's output given the labour and capital inputs, n_t and k_t. In the context of the model, z_t is the time t realization of the economy's technology which is assumed to be a

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[2] These are: $u(0)=0$, $u_i(0)=\infty$, $u_i(\infty)=0$, where u_i is the first derivative with respect to both arguments of the utility function.

random variable. Here, z_t is assumed to follow a stationary Markov process where the distribution at time *t* depends on the realization at *t-1*, but is otherwise independent across time. That is, z_t can be assumed to follow an AR(1) process of the form:

$$\ln(z_t) = \rho \ln(z_{t-1}) + \varepsilon_t \tag{2.3}$$

where $\varepsilon_t \sim iid(0,\sigma_\varepsilon^2)$, and $|\rho|<1$ measures the persistence of the shock. Capital accumulation in this economy follows

$$k_{t+1} = I_t + (1-\delta)k_t \tag{2.4}$$

where I_t is the amount invested at time t, and $0 \leq \delta \leq 1$ is the capital depreciation rate.

Due to the assumption that the economy is composed of identical households, the problem considered can be that of a *representative* household. In such an economy output could either be consumed, or invested. After observing a shock to the technology, the agent chooses her intertemporal consumption and investment to maximize her utility over the infinite horizon. That is, z_t and k_t are state variables, while c_t and k_{t+1} are control variables. In this economy, labour markets clear, and the agent's problem is to maximize the objective function (2.1) subject to equations (2.2)-(2.4), and according to the goods market clearing constraint

$$y_t = c_t + I_t \tag{2.5}$$

An analytical (closed-form) solution to this problem cannot usually be found since the decision rules will be non-linear. However, to see a simple example of a propagation mechanism, consider the following special case. Let the household's utility *u* be described by the following log-linear function

$$u(c_t, 1-n_t) = \theta \log(c_t) + (1-\theta)\log(1-n_t) \tag{2.6}$$

Furthermore, assume that the economy's production can be described by a Cobb-Douglas production function

$$y_t = z_t n_t^{\alpha} k_t^{1-\alpha} \tag{2.7}$$

where α is labour's share in the production function. To ensure that an analytical solution is found, assume complete depreciation each period, $\delta=1$.

This system can be solved for the social planner's problem which is equivalent to the competitive equilibrium in this framework. Decision rules for consumption and capital accumulation can therefore be found by setting up the first orders conditions for a maximum[3]. Denoting the Lagrange multiplier by λ, the first order conditions are:

$$c_t + k_{t+1} = z_t n_t^{\alpha} k_t^{1-\alpha} \tag{2.8}$$

$$\theta / c_t = \lambda_t \tag{2.9}$$

$$(1-\theta)/(1-n_t) = \alpha \lambda_t z_t n_t^{\alpha-1} k_t^{1-\alpha} \tag{2.10}$$

$$\lambda_t = (1-\alpha)\beta E_t \lambda_{t+1} [z_{t+1} n_{t+1}^{\alpha} k_{t+1}^{1-\alpha}] \tag{2.11}$$

After manipulating the above first order conditions we can arrive at the following decision rules:

$$n_t = \alpha\theta / [\alpha\theta + (1-\theta)(1-\beta(1-\alpha))] \tag{2.12}$$

$$c_t = [1-(1-\alpha)\beta] n_t^{\alpha} z_t k_t^{1-\alpha} \tag{2.13}$$

$$k_{t+1} = (1-\alpha)\beta n_t^{\alpha} z_t k_t^{1-\alpha} \tag{2.14}$$

A number of direct conclusions arise from the time-invariant decision processes (2.12)-(2.14). First, the decision rule governing the motion of labour supply, n, is invariant since it only depends on the parameters α, β and θ and not on any of the state variables. This result derives from the structure of the utility function where income and substitution effects exactly cancel each other out in the case of full depreciation, leaving leisure (and thus labour supply) unaffected. Second, with log z_t following an AR(1) process, it can be easily shown that log y_t, log c_t, and log k_t will follow AR(2) processes, which is noteworthy since the logarithms of these

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[3] Alternatively, the system can be solved by setting up Bellman's equation and using dynamic programming techniques. In this example it is more straight-forward to use the first order conditions.

variables in detrended[4] aggregate quarterly U.S. data can be quite well described by AR(2) processes. Quite clearly, the model is successful in replicating the pro-cyclicality of consumption, investment and the average product of labour. The model fails in other dimensions such as its constant employment feature, and the equal variance in the fluctuation of consumption and investment, which clearly violates empirical observation.

2.2 Quantitative comparison of results

The original work of the RBC stream provided more complex models than the above model. As a result, no analytical solution was available for those models which had to be numerically approximated and then simulated. Although these models outperform the basic model outlined above, they also have certain counterfactual properties. In particular, we examine the models by Kydland and Prescott (1982) and Hansen (1985). Kydland and Prescott's model features incomplete depreciation, and a "time to build" feature, where capital becomes productive in the fourth period after the initial investment, requiring additional investment in the second and third periods. The model also features a technology shock containing persistent and transient components, and where producers hold inventories as a factor of production. In addition, leisure is a distributed lag of past leisure consumed. The model by Hansen (1985), on the other hand, features an "all or nothing" indivisible labour characteristic where *ex-ante* identical workers differ *ex-post* according to the result of a lottery that determines whether they work a full amount of hours or none at all[5]. Tables I and II below summarize key results of the basic model and the Kydland and Prescott (1982) and Hansen (1985) models and compares them to U.S. data.

In simulating the results, each of these models calibrates the variance of the technology shock so that the filtered simulated output matches that of the filtered data. As the tables show, these RBC models are able to capture some of the correlations that exist in aggregate data between various macroeconomic variables. As can be seen in tables I and II, the more sophisticated models of Kydland and Prescott (1982) and Hansen (1985) produce better fit with

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[4] Aggregate data are usually detrended in RBC literature by using the Hodrick-Prescott filter.

[5] This is modeled by introducing a new "commodity" in the form of a traded contract between the firm and the household where the household works h_o with a certain probability π, or supplies no work with probability $(1-\pi)$. Firms provide complete unemployment insurance to the workers so that the workers get paid in both cases.

the U.S. data. However, it is clear that the structure of the RBC framework seems to do rather poorly in replicating the movement of the hours worked and productivity (average productivity of labour) in that the volatility of both variables is understated by the models. Furthermore, the models also fare poorly in predicting the contemporaneous correlation of these two variables with output. In this measure, all three RBC models predict a very high correlation of hours worked and output (nearing unity). It is important to note, however, that the models do match observations well for the contemporaneous correlation of consumption, investment and capital stock with output.

A number of issues arise within the RBC framework, the first of which concerns measurement. Under the technique of calibration, the variance of the technology shock is adjusted until the variance of output in the model matches that of the real world. The issue then becomes the plausibility of the shock used and whether it can be justified in comparison to the computed Solow residual arising from the production function (which the technology shock is supposed to model). Although this was first thought to be a major issue by sceptics of the RBC methodology, additional studies revealed that the magnitude required for the technology variance is close to the computed Solow residual.

Table I: Standard Deviations of Percentage Departures from Trend

	U.S. Economy*	Basic Model	Kydland-Prescott	Hansen
Output	1.76	1.76	1.76	1.76
Consumption**	1.29	0.55	0.44	0.51
Investment	8.60	5.53	5.40	5.71
Capital Stock	0.63	0.47	0.46	0.47
Hours	1.66	0.91	1.21	1.35
Productivity	1.18	0.89	0.70	0.50

Corresponds to Table 1.1 in McCallum (1989)

*/ Seasonally adjusted quarterly data from 1955.3-1984.1
**/ Including consumption of durables.

Table II: Contemporaneous Correlation with Output (Departures from Trend)

	U.S. Economy*	Basic Model	Kydland-Prescott	Hansen
Consumption	0.85	0.89	0.85	0.87
Investment	0.92	0.99	0.88	0.99
Capital Stock	0.04	0.06	0.02	0.05
Hours	0.76	0.98	0.95	0.98
Productivity	0.42	0.98	0.86	0.87

*/ Corresponds to Table 1.2 in McCallum (1989).
**/ Seasonally adjusted quarterly data from 1955.3-1984.1.

A more concrete issue, however, is the ambiguity surrounding the measurement of the Solow residual. For example, the Solow residual will overestimate technical change if no adjustment is made for changes in labour utilization. Therefore, any labour hoarding activity will likely result in an overestimation of the degree of the productivity shock in the RBC model. This was the finding of Burnside, Eichenbaum and Rebelo (1993) who estimated that after accounting for labour hoarding behaviour, the variance of technology shocks is about 50 percent less than that implied by standard RBC models. As such, Burnside *et al.* illustrate that RBC models substantially overstate the importance of technology shocks in explaining aggregate fluctuations.

Another issue is whether it can be rationalized that the economy is likely to be experiencing aggregate, economy-wide supply shocks every quarter. That is, although the "supply-side" shocks of the type encountered during the 1970s oil-shock would appear in the production function residual and would affect the whole economy, other (sector-specific) shocks are ignored in these models.

Finally, and perhaps most importantly from a policy perspective, monetary and fiscal policies are completely ignored in these models. This omission poses several conceptual problems. First, although the RBC model does not completely rule out a role for monetary policy, it does indicate that monetary policy is of relatively little importance in producing business cycles. This particularly distinguishing feature of the RBC methodology has come under significant attack for marginalizing a potentially significant explanation of aggregate behaviour of economic variables in the real world. Another problem arises from the exclusion of fiscal policy as there is doubt that a Pareto optimum exists given the degree of distortionary taxation

required to finance government consumption in the real economy. This may pose a problem to the RBC framework that relies in its solution algorithm on the assumption that a Pareto optimum is equivalent to the competitive equilibrium of the economy.

To deal with these and other shortcomings of the RBC framework, new-classical researchers have turned their efforts to trying to extend the stochastic general equilibrium framework to include a role for government, monetary policy and the terms of trade, and also in incorporating nominal price and wage rigidities to better explain aggregate macroeconomic fluctuations.

3. Modelling Fiscal and Monetary Policies

This section serves as an introduction to the on-going research in modelling the effects of government fiscal and monetary policies. In their work incorporating fiscal policy in a stochastic general equilibrium framework, Christiano and Eichenbaum (1991) provide an example of the modelling strategy involved in transgressing RBC models. Although other studies extending the Christiano-Eichenbaum framework have emerged, this section will be limited to the Christiano-Eichenbaum work because of its representative nature and due to the limited number of ways that fiscal policy has been incorporated into a stochastic RBC framework. This section also shows that views on monetary policy are more diverse. As in other streams of economic literature, the role and interaction of money remains an open area of research and is the topic of considerable debate. In the context of the new-classical research, much of the literature has focused on incorporating money through a *cash-in-advance* (CIA) constraint, or through a mechanism that bears resemblance to the CIA set-up. This section will survey three such methods of modelling money in an equilibrium model of aggregate fluctuations.

3.1 Fiscal policy

One well-documented shortcoming of the RBC work is its inability to replicate observed labour market phenomena such as low correlation between average labour productivity and hours worked. The fact that the basic RBC model predicts a correlation in the magnitude of 0.9, while the observed correlation in the U.S. data is close to zero reveals the fundamental problem in

translating the RBC framework to public policy. A possible path for the evolution of new-classical economics has been to abandon the strict RBC framework by incorporating alternate features that improve the quantitative aspects of the model. Christiano and Eichenbaum (1991) conjectured that this high correlation between hours worked and productivity could be broken by considering "measurable" economic shocks that shift the labour supply function. Candidates for these shocks are those arising from government spending, tax changes and innovations in money supply. In what follows is an exploration of the fiscal policy shocks as a possible explanation for aggregate fluctuations in a model of perfectly flexible prices. Here, it is important to note that fiscal policy operates through the supply side, and not through the usual multipliers associated with Keynesian models. This is due to the fact that, in the presence of perfectly flexible prices in the new-classical framework, demand shocks will not generate significant effects.

Christiano and Eichenbaum (1991) start with the simple model explored above, but consider a more general utility form, of which the above model is a special case. Specifically, assume that the social planner's problem is to maximize the following function, where utility is a function of both consumption and leisure:

$$E_o \Sigma_{t=0}^{\infty} \beta^t \, [\log(c_t) + \gamma V(N-n_t)] \tag{3.1}$$

This model has as two special cases of the *divisible-labour model* (as in the basic model), and the *indivisible-labour model* (as in Hansen (1985) described above) where $V(\cdot)$ can be

$$V(N-n_t) = \ln(N-n_t) \text{ for all } t \tag{3.2}$$

or,

$$V(N-n_t) = (N-n_t) \text{ for all } t \tag{3.3}$$

The distinguishing feature in this model is characterized by consumption which is described by

$$c_t = c_t^p + \theta g_t \tag{3.4}$$

where c_t^p is private consumption, g_t is government spending, and θ is the magnitude of the derivative of marginal utility of c_t^p with respect to g_t. As far as the agents are concerned,

government spending is a stochastic process beyond the control of the agents and is independent of present or past values of the endogenous variables.[6] Technological shocks, production, capital accumulation and the aggregate resource constraint are described in a manner similar to the previous RBC model:

$$y_t = (z_t n_t)^{1-\alpha} k_t^{\alpha} \tag{3.5}$$

$$z_t = z_{t-1} \exp(\varepsilon_t) \tag{3.6}$$

$$c_t^p + g_t + k_{t+1} - (1-\delta)k_t = y_t \tag{3.7}$$

where ε_t iid$(\varepsilon,\sigma_\varepsilon^2)$. The social planner chooses at time 0 $\{c_t, k_{t+1}$, and n_t for $t \geq 0\}$ subject to the above constraints and to the initial stock of capital, and to the stochastic shocks z_t and g_t. In this model it is assumed that the joint law of motion for g_t and z_t follows

$$\ln(\tilde{g}_t) = (1-\rho)\ln(\tilde{g}) + \rho \ln(\tilde{g}_{t-1}) + \mu_t \tag{3.8}$$

where $|\rho|<1$, $\ln(\tilde{g})$ is the mean of $\ln(\tilde{g}_t)$, and μ_t iid$(0,\sigma_t^2)$.

Table III: Selected First Moment Properties

	U.S. Economy*	Divisible Labour	Indivisible Labour
$\Delta \log c_t^p$	0.0045	0.0040	0.0040
$\Delta \log k_t$	0.0047	0.0040	0.0040
$\Delta \log g_t$	0.0023	0.0040	0.0040
$\Delta \log y_t$	0.0040	0.0040	0.0040
$\Delta \log n_t$	0.00002	0.00001	0.00001

Corresponds to Table 1 in Christiano and Eichenbaum (1991)

*/ Seasonally adjusted quarterly data from 1955.4-1983.4

[6] This will ensure that the social planner's problem coincides with the economy's competitive equilibrium.

The decision rules arising from this model are approximated using log-linear approximation techniques, and in contrast to the calibration technique used by early RBC work, this model is estimated using the Generalized Method of Moments (GMM) procedures. This allows the researchers to evaluate the degree of certainty of the estimates of the model's parameters.

As table III shows, the incorporation of government spending improves the quantitative performance of the model. Specifically, although the model continues to generate a strong correlation between labour productivity and hours supplied, the correlation is smaller than the one obtained through earlier RBC models. Furthermore, the fit of the *indivisible-labour* model to actual U.S. data is rather good. The model continues to inadequately portray fluctuations in the labour market as the joint null hypothesis, that both the correlation and the volatility between labour productivity and hours supplied predicted by the model are true, is overwhelmingly rejected.

The mixed results emerging from this model highlight the difficulty in accurately predicting the movements of labour market variables in the new-classical research. Although the model offers a significant departure from the RBC framework, it has the unattractive feature that government spending is exogenous. Thus, although the inclusion of fiscal policy enhances the quantitative and qualitative aspects of the model, no optimal level of government can be inferred from the model at this point. Future new-classical work will have to address modelling government behaviour as an endogenous or quasi-endogenous manner. In so doing, an endogenous component of government spending implies that the government responds optimally to the exogenous shocks that set off the business cycle. This endogenous component of government spending is chosen by the government to maximize the utility of the agent and the optimal path of government spending would be restricted to be time consistent. Preliminary work has been done on this by Ambler and Paquet (1993).

However, as Baxter and King (1993) have illustrated, fiscal policy can be modeled in an alternative way. In their model of fiscal policy in general equilibrium, Baxter and King measure the dynamic responses to government purchases in a closed one-sector economy. Specifically, Baxter and King address the macroeconomic effects of temporary and permeant changes in the level of government purchases, and test the importance of financing decisions. An additional

attractive feature of the Baxter-King model is that it considers the dynamic equilibrium effects of increases in public capital stock. Consistent with the equilibrium approach, the model is parameterized and calibrated to match stylized facts of the United States economy. Therefore, when simulated, the model is able to produce quantitative results (percentage changes) in output, consumption, and other endogenously determined variables.

As before, the economy is described by preferences, technology and the resource constraints. The infinitely-lived individual in this economy has preferences of the form:

$$E_o \Sigma_{t=1}^{\infty} \beta^{(t-1)} [\log(c_t) + \theta_L \log(L_t) + \Gamma(G_t^B, K_t^G)] \quad (3.9)$$

where L_t is leisure; G_t^B denotes basic government purchases that do not affect the marginal utility of private consumption or the marginal product of private factors of production; K_t^G denotes public capital; and Γ is a function that is assumed to be non-decreasing in each of its arguments.

Production in this economy follows an *increasing returns to scale* technology of the form:

$$Y_t = AK_t^{\theta_K} N_t^{\theta_N} (K_t^G)^{\theta_G} \quad (3.10)$$

where K_t is the private capital stock; K_t^G is the stock of public capital; and N_t is the labour input. This technology features constant returns to scale over private inputs (i.e., $\theta_N + \theta_K = 1$). Denoting public and private gross investment by I_t^G and I_t, respectively, capital stock will evolve according to:

$$K_{t+1} = [(1-\delta_K)K_t + I_t] \quad (3.11)$$

and,

$$K_{t+1}^G = [(1-\delta_K)K_t^G + I_t^G] \quad (3.12)$$

To complete the dynamic system, consider the resource constraints facing the individual and the government:

$$L_t + N_t = 1 \quad (3.13)$$

$$C_t + I_t = (1-\tau_t)Y_t + TR_t \quad (3.14)$$

$$\tau_t Y_t = G_t + TR_t \quad (3.15)$$

where τ_t represents the tax rate on output, TR_t are transfers to the individuals, and G_t is the sum of government purchases and gross public investment.

Utilizing the above analytical framework, unanticipated permanent increases in government spending are found to increase output by more than a factor of one, implying the presence of a *multiplier* effect. This result derives from the fact that government purchases reduce consumption (due to the total endowment constraint) and thereby increase labour input as agents work more to smoothen consumption over time. The increase in labour input due to a higher marginal product of labour in the future, which in turn implies higher future interest rates. The increase in interest rates increase investment, with the final effect of increasing output by more that a factor of one. This result is found to be sensitive to the type of tax imposed to finance government consumption. With distortionary income taxes, government consumption no longer increases output by more than unity, implying that government consumption can act as a drain on the economy. An interesting result emerging from this model is the one involving productive public capital investment. Depending on the level of productivity of public capital[7], output increases by well over unity, implying large productivity gains from public capital provision.

A noteworthy feature of the Baxter-King (1993) model is that no moments are calculated for the generated series for output, consumption, and investment. This is a deviation in procedure from the standard dynamic general equilibrium new-classical analysis that usually attempts to compare generated series to actual observed relationships in the economy. Therefore, until further work on estimating the model is undertaken, it is impossible to judge if the Baxter-King model adequately fits the data.

3.2 Monetary policy

The incorporation of money has been high on the new-classical research agenda. Several models have appeared where money is incorporated into the stochastic general equilibrium framework, the simplest version of which incorporates money into the economy through a cash-

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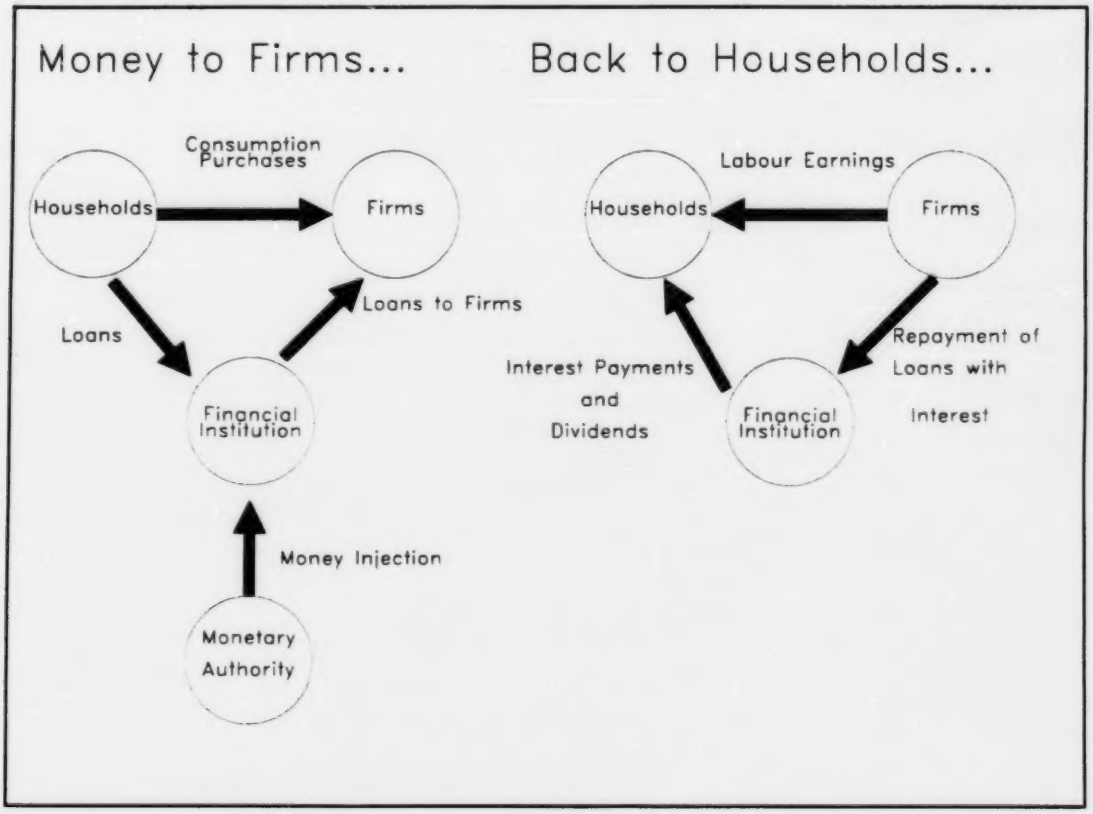
[7] The parameter is allowed to vary between 0 (i.e., public capital does not induce private sector productivity) and 0.4. This range reflects the estimation results from microeconomic studies on the relationship between private sector productivity and the availability of publicly-provided infrastructure.

in-advance constraint. However, more elaborate modelling of money has appeared in Lucas (1990), Fuerst (1990), and Christiano (1991).[8] The problem of modelling money in micro-based macroeconomic models is due to the fact that money is usually dominated by other assets in the economy. Therefore, an elaborate structure has to be put in place to rationalize the holding of money. Although traditional theory had incorporated money in the utility function (i.e. agents derive utility from holding money *per se* rather than derive utility from the future consumption that money represents) this approach has been overshadowed by the cash-in-advance alternative.

Chart 1



The cash-in-advance constraint obliges agents to hold money because current purchases in the economy can only be paid for by the money held over from the previous period.

[8] It is important to keep in mind that these models do not deviate from the Walrasian framework where prices are perfectly flexible.

Alternatively, one can think of a household in the economy as composed of two individuals: an earner and a spender. At the beginning of each period, the earner supplies the work effort and gets paid at the end of the period while the spender *simultaneously* purchases goods. Since both individuals can only interact *at the end of each period*, the spender has to finance the household's purchases by using the money earned in the previous period. Other than the fact that this contradicts the factual observation of the pervasiveness of credit in the real world, this type of constraint seems to capture an important role for money. As can be seen, timing is crucial in this model of money, and it is variations in this timing that distinguish the three competing models discussed here. Chart 1 outlines the cash flow in the model economy.

This simple notion of money can be quantified in the new-classical model discussed throughout this paper. In addition to the set-up introduced in section 2 above, household face the cash-in-advance constraint in the form

$$p_t c_t = M_t - L_t \tag{3.16}$$

where L_t denotes the loans that households make to banks; M_t is the money held; and p_t is the price level of the one good available in the economy. From here we can see that the innovations in the money supply (i.e. monetary shocks) will affect individual decisions under certain assumptions. Monetary injections are modelled similar to technology shocks

$$x_t = (1-\rho_x)x + \rho_x x_{t-1} + \varepsilon_x \tag{3.17}$$

Again, ε_x iid(x,σ_x^2), with x as the unconditional mean of the shock, and $|\rho_x|<1$. The monetary and technology shocks are also assumed to be independent of each other.

As mentioned earlier, timing is crucial in this model, and as a result subtle differences in the timing of the revelation of the shocks cause fundamental differences between alternative models using this framework. Table IV describes differences in timing between the three competing models of money in the post-RBC new-classical framework.

The variance in the timing results in several features. In the Fuerst-Lucas, and the sluggish capital, models there will be noise in the portfolio decisions made since the monetary

shock will occur after the decision on how much to consume has been made. In the sluggish capital model, firms also face an uncertainty due to investment decisions being made before shocks to money and technology are revealed. These differences result in rather large quantitative results across these models as outlined in table V.

Table IV: Timing of Shocks in Alternative Monetary Models of the Business Cycle

Basic Cash-in-Advance	**Fuerst-Lucas**	**Christiano (Sluggish Capital)**
SHOCKS ARE REVEALED	portfolio decision made	portfolio decision made
⬇	⬇	⬇
portfolio decision made	**SHOCKS ARE REVEALED**	investment decision made
⬇	⬇	⬇
labour-leisure choice	labour-leisure choice	**SHOCKS ARE REVEALED**
⬇	⬇	⬇
investment decision made	investment decision made	labour-leisure choice
⬇	⬇	⬇
hiring decisions made	hiring decisions made	hiring decisions made

Unfortunately, it is extremely difficult to judge which of the three models best describes reality since there is no one model that consistently outperforms the rest in predicting all real and nominal variables. As such, although the sluggish capital model is preferable because it can replicate the liquidity effect[9] while the other two models cannot, it fares rather badly in predicting all the real variables. This is somewhat disheartening since it seems that the model can only be improved in certain respects at the cost of others. However, it does seem that the models are becoming more sophisticated and promise to improve their over-all performance in the near future.

[9] The liquidity effect is thought to be an established empirical regularity where positive money supply shocks drive short-term interest rates down.

Table V: Volatility in the Data and the Models (Departures from Trend)*

	U.S. Economy	Basic C-I-A	Fuerst-Lucas	Sluggish Capital
Output	0.017	0.013	0.013	0.015
Consumption	0.490	0.630	0.880	0.990
Employment	1.000	0.290	0.300	0.520
Investment	2.590	2.990	3.130	2.660
Price Level (CPI)	0.016	0.015	0.015	0.018
Nominal Interest Rate (T-Bill)	0.0033	0.0022	0.0021	0.0140
CORRELATIONS WITH OUTPUT				
Consumption	0.68	0.98	0.87	0.90
Employment	0.75	0.91	0.92	0.82
Investment	0.90	0.98	0.71	0.57
Price Level (CPI)	-.55	-.89	-.89	-.91
Nominal Interest Rate (T-Bill)	0.30	0.11	0.13	-.38

Corresponds to Tables 3-5 in Christiano (1991)

*/ Logged and then detrended using HP filter.

4. Modelling the Open Economy

The open economy feature of new-classical models seems to be of growing importance as the open economy extensions of the dynamic general equilibrium system can only lend more credibility to the predictions of the model. This is a particularly salient point for Canada which seems to fit quite well the "small-open economy" description that is often alluded to in the literature. However, opening the economy can seriously alter the co-movements of variables established in closed economies. Furthermore, the open economy would be obliged to answer additional puzzles regarding the inter-country movement of variables. This section discusses these puzzles and outlines two seminal works by Stockman and Tesar (1990) and Backus, Kehoe and Kydland (1992) in attempting to answer these puzzles.

Economic theory would predict that full cross-country insurance would prevail in a world of independent supply and demand shocks across countries (that is, under a scenario where some countries would experience slowdowns at the time others experience booms). By a simple consumption smoothing argument, individuals will prefer to pool their risks to smooth their consumption across states of the world. If in one period country A experiences a positive shock while country B does not, consumption will rise in country A, but less than output due to consumption smoothing. Having pooled its risk, consumption in country B will also rise. Thus country A will experience a trade surplus, while country B will experience a trade deficit. As such, we would expect consumption across countries to be highly correlated, output to be less correlated and the trade balance to be pro-cyclical due to consumption smoothing.

In reality, there is rather low cross-country correlation in consumption. In fact the Canada-U.S. consumption correlation is one of the highest among the G-7, and yet it is only 0.442 on aggregate. Furthermore, the cross-country consumption correlation is lower than that of output-- a definite anomaly in the face of the insurance/consumption-smoothing argument. Furthermore, it has been documented that the trade balance is counter-cyclical or acyclical[10] which again contradicts the simple open economy theory outlined above. A further puzzle is the one well-documented by Feldstein-Horioka where savings and investment are strongly positively correlated within most countries.

It is therefore not surprising that the Backus *et al.* (1992) open economy RBC model falls victim to all these puzzles. The production structure and parameter values are identical in the two countries, and there is perfect capital mobility. Each country produces one good (the same good, for that matter) using domestic labour. The only distinction between the models involves the specific Solow technology shocks that impact the technology of each country. The model is solved by considering the social planner's problem for the two economies. That is, the model considers a social planner's problem of the form:

$$\max \psi \left[E_o \sum_{j=0}^{\infty} \beta^t u(c_t^h , l_t^h)\right] + (1-\psi) \left[E_o \sum_{j=0}^{\infty} \beta^t u(c_t^h , l_t^h)\right] \qquad (4.1)$$

[10] The cyclical behaviour of the trade account is sensitive to the method of detrending and to the time period considered. This point has been documented for various G-7 countries by Stockman and Tesar (1990).

where ψ is the "country weight" which, for the sake of simplicity, is assumed to be equal to 0.5 for both countries in the model.[11] Not surprisingly, the model produces a cross-country consumption correlation that is implausibly high, a trade account that is strongly pro-cyclical, and a cross-country output correlation that is negative compared to the positive one found in the real world.

Backus *et al.* alter their model in two ways to improve its performance. First, capital mobility is restricted by introducing trading frictions in the form of transportation costs. Although these frictions reduce the variability in investment and increase the correlation between savings and investment, the model remains unable to produce low correlations in cross-country consumption. Another extension presented by the authors features large technological spill-overs that are able to produce positive cross-country correlations in output. This, however, cannot be viewed as a valid explanation of positive cross-country output correlations since is has been well documented that Solow residuals are not highly correlated across countries.

Stockman and Tesar (1990) provide an alternative strategy. Their open economy model introduces two goods: one that can be traded freely, and another that is non-tradeable.[12] By incorporating this feature, the theoretical possibility of full insurance is pre-empted since the shocks affecting the non-traded commodity are un-insurable. The model also has "taste-shocks" that affect the households' preferences for consumption. The difficulty with these shocks is, of course, one of measurement.[13] Nonetheless, they feature an additional form of country-specific shocks that better explain aggregate macroeconomic fluctuations. These shocks can be thought of as shifting demand that arise because of fiscal or monetary policy. It is important to note that the exact nature of these taste shocks has to be more clearly explained in future research due to their importance in improving the fit of the model. The model is then calibrated to an "average" industrialized country, capturing the idea of trade between two identical countries.

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[11] The weights can be thought of as parameters expressing the relative wealth or relative size of the two economies.

[12] These non-traded goods can be empirically important. As Stockman and Tesar estimate in their paper, these goods compose half of GDP in Canada and the United States.

[13] As the Stockman-Tesar paper suggests, these taste shocks are modelled in a way that is very similar to the fiscal shocks explored earlier.

With a non-traded goods sector encountering a favourable technology shock in country A, resources in that country are shifted from the traded towards the non-traded sector, reducing the production of the traded commodity. Total output increases and consequently increases consumption of both traded and non-traded goods. Although total consumption increases by less than output due to consumption-smoothing, traded goods consumption actually increases more than output in that sector, inducing a trade account deterioration. Thus, country B experiences a trade account surplus causing it to increase its production and reduce its consumption due to the higher price of the traded good. Work effort increases and total consumption likely decreases in country B due to these dynamics. Thus, the model generates a counter-cyclical trade account, low cross-country consumption correlations and positive cross-country output correlations.

The model fares very well empirically, but the success depends on calibrating the taste shock that is not very well defined. Without reliance on the taste shocks (i.e. only Solow residuals are considered), the model does relatively well in predicting domestic and international co-movements. The largest counter-factual result emerging form the model concerns the movement of the relative prices of the traded and non-traded goods with respect to consumption. As table VI shows, the model is quite successful in reproducing co-movements in economic variables of a magnitude that compares well quantitatively with average movements across industrialized countries.

It is, therefore, apparent that including non-traded goods in the new-classical model greatly improves its performance. Future research on open economy models will undoubtedly focus on maintaining this feature in addition to other extensions. Research has already begun by examining incomplete international asset markets, which give rise to low cross-country consumption correlations.

Table VI: Comparison of the Stockman-Tesar Results to the Data (Standard Deviations)

	Average Economy	Case 1	Case 2	Case 3
AGGREGATE				
Output	2.53	2.58	2.60	2.62
Consumption	2.03	1.54	1.69	1.94
Employment	1.61	1.90	1.99	2.35
Investment	5.53	5.84	6.01	6.03
Capital	2.96	2.73	2.88	2.62
TRADED GOODS SECTOR				
Output	3.45	3.21	3.24	3.40
Consumption	3.32	1.08	1.12	3.18
Employment	2.17	1.78	1.86	2.47
Investment	7.02	9.22	9.28	9.27
Capital	2.50	2.57	2.62	2.62
NON-TRADED GOODS SECTOR				
Output	2.02	2.86	2.91	2.94
Consumption	2.78	1.86	2.35	2.37
Employment	1.36	1.12	1.59	1.64
Investment	6.51	6.13	6.41	6.47
Capital	3.64	2.97	3.10	3.16
INTERNATIONAL CROSS-COUNTRY CORRELATIONS				
Consumption	0.50	0.78	0.63	0.33
Output	0.64	0.64	0.63	0.53
Trade Balance:Output	-.47	-.42	-.42	-.47
DOMESTIC PRICE-QUANTITY CORRELATIONS				
Relative Price : Output	0.28	-.70	-.56	-.42

Corresponds to Table 14 in Stockman-Tesar (1990)

Case 1: Technology shocks to the countries production.
Case 2: Taste shocks to the Non-traded goods.
Case 3: Taste shocks to home produced goods.

5. Nominal Rigidities in New-Classical Models

Although the monetary models discussed in section 3 included a role for monetary policy, they did not allude to the much discussed role of nominal rigidities in amplifying the effects of monetary policy. As such, the presence of nominal rigidities has until now been exclusive to Keynesian models. In contrast to the models incorporating monetary policy through a cash-in-advance type constraint, there is now a growing literature on new-classical models that features wage and price stickiness. This can be seen as a significant departure from the models discussed earlier where prices and wages adjust instantaneously after the dynamic system receives a shock. Consequently, models with nominal rigidities help explain many of the features of the monetary business cycle, and thereby hold considerable promise for explaining the response of the economy to monetary shocks. In what follows, a new-classical model with nominal rigidities is explored to illustrate the features and results of this promising stream of research.

Although considerable research focusing on nominal rigidities has begun to emerge, this section focuses on the work of Robert King (1991) in introducing nominal price and wage inflexibilities in an otherwise neoclassical framework. King seeks to reproduce the real world post-war observation of a smooth triangular response of output, consumption, investment, and labour input to a monetary shock. Such impulse functions are characterized by a smooth triangular shape with a peak of 6-8 quarters and a duration of approximately four years. These characteristics cannot be explained in the context of a real business cycle model, however, because in such a model money would be neutral. Therefore, to emphasize the role of money in the business cycle, price or wage stickiness is added.

5.1 A model of wage stickiness

The model features the general specification of maximizing utility, subject to time and resource constraints and in accordance to production and capital accumulation which are common to the stream of models discussed so far. In addition, however, a simple log-linear money equilibrium condition is posited:

$$\ln(M_t) = \ln (P_t) + \nu \ln(y_t) \qquad (5.1)$$

where M_t is the stock of money, P_t is the nominal price of a unit of output, and v is the income elasticity of money demand. Note that equation (5.1) abstracts from the nominal interest rate sensitivity of money demand. In addition, contracts for wages in the future are set at the present time. That is, the nominal wage that will prevail at time t+s, is set at time t, and is the rational expectation of the wage that will clear the market at time t+s. Under such a scenario, the demand-determined labour input at time t requires that:

$$\ln ({}_{t-s}W_t) = \ln(P_t) + \ln(MPN_t) \tag{5.2}$$

where ${}_{t-s}W_t$ is nominal wages at time t set at time t-s, and MPN_t denotes the marginal product of labour. In this model, prices are assumed to be flexible. It can be seen that pre-determined nominal wages contain a powerful channel where money can affect real activity, provided that firms operate along their short-run demand schedules for labour. Combining equation (5.1), (5.2) with the Cobb-Douglas production function (2.7), gives the following relation:

$$\begin{aligned} \ln (N_t) = {} & [\ \ln(M_t) - \ln({}_{t-s}W_t)]/[1-\alpha(1-v)] + [(1-v)\ln(z_t) \\ & + \ln(\alpha) + (1-v)(1-\alpha)\ln(k_t)]/[1-\alpha(1-v)] \end{aligned} \tag{5.3}$$

$$\begin{aligned} \ln (y_t) = {} & \alpha[\ \ln(M_t) - \ln({}_{t-s}W_t) + \ln(\alpha)]/[1-\alpha(1-v)] \\ & + [1/(1-\alpha(1-v))]\ \ln(z_t) + [(1-\alpha)/(1-\alpha(1-v))]\ \ln(k_t) \end{aligned} \tag{5.4}$$

where N_t is labour; k_t is capital; y_t is output; and α is the labour share of production. Equations (5.3) and (5.4) reveal the dynamics in which money affects output and employment. In this model, wages evolve over time according to the rational expectations that would equate labour demand and labour supply. These will be the wages that would prevail in the *real* model at time t+s given that capital is accumulated according to the *sticky wage* model. Therefore, wages evolve according to:

$$\ln ({}_tW_{t+s}) = E_t \ln(P_{t+s}) + E_t \ln(MPN^*_{t+s}) \tag{5.5}$$

where MPN^*_{t+s} is the market-clearing marginal product which can be derived from the real model, and which characterizes the market-clearing operation of the economy.

The above model can be interpreted as a staggered wage model where wage contracts are set to the expected market-clearing conditions in the terminal contract periods, but follow the set nominal wage during other periods where there is a pre-existing wage.

5.2 A sticky price model

The sticky price models are similar to the sticky wage models in that they provide a mechanism for monetary policy to affect real variables. Wages are assumed to be flexible. The predetermined price level ${}_{t-s}P_t$ implies that, according to the monetary equilibrium condition (5.1), a 1 percent change in money will result in a $1/v$ percent change in output:

$$\ln(y_t) = [\ln(M_t) - \ln({}_{t-s}P_t)]/v \tag{5.6}$$

Substituting into the production function, the effect on labour input is:

$$\ln(N_t) = [\ln(y_t) - \ln(z_t) - (1-\alpha)\ln(k_t)]/\alpha \tag{5.7}$$

implying that a one percent change in the money supply will necessitate a $1/\alpha v$ percent change in labour input. It is assumed that workers are paid the wage that keeps them on their short-term labour supply schedule. Prices are set according to rational expectations of equilibrium values:

$$\ln({}_tP_{t+s}) = E_t \ln(P^*_{t+s}) \tag{5.8}$$

Similar to the sticky wage model, equilibrium prices can be determined from the dynamics of the real model.

5.3 Quantitative results

The sticky wage model captures the general business cycle features, and predicts that consumption is less than half as volatile as output, while investment is about two times as volatile. However, the model predicts a counter-cyclical real wage, contrary to the empirical evidence in the U.S. data. Moreover, it predicts that real interest rates display a small (10 to 20

basis points) *positive* response to the monetary business cycle. This is admittedly a puzzle, as the real interest rate response is observed to be negative in post-war U.S. data. The model also cannot account for the liquidity effect discussed in section 3, since the expected inflation more than offsets this liquidity effect. Finally, the model does a poor job in replicating price level movements.

The sticky price model also captures well the same elements of consumption, investment and output. Similar to the sticky wage model, the sticky price model predicts counter-factual movements in the real interest and wage rates, and cannot replicate the liquidity effect for the nominal interest rate. The model, however, fares better in terms of its implications for the price level movement. Unfortunately, the extent of the sluggishness in the price level can only be captured to a certain degree.

The above model by King has generated much enthusiasm since it has brought new-classical models closer to becoming viable policy tools. As such, work on incorporating nominal rigidities into an otherwise new-classical model has been taken up by several researchers, and working models have begun to emerge. Notable among them is work by Cho and Phanuef (1993), Mark and Watson (1992), and Lucas (1989). This work indicates that aggregate fluctuations can be modelled well by new-classical models with nominal wage contracts. The challenge, however, is to find micro-economic reasons why these nominal rigidities exist in the economy, thereby making these models more internally consistent.

6. Conclusions

This paper has surveyed the new-classical class of models that has generated much interest in academia since the late 1970s, but which have not yet become a viable tool for policy makers. As this survey has shown, however, these models are slowly becoming more relevant from a policy perspective as they have begun to incorporate realistic real world features into their framework.

One particularly promising advance in the new-classical stream has been the work in

incorporating nominal rigidities into the stochastic general equilibrium framework. Although such research is preliminary, the results emerging from it are encouraging. Through such models with nominal rigidities, the impact of monetary policy on real variables can be replicated to closely match real world post-war experience. Extensions to this model are possible, and can lead to substantial improvement in fitting the data. One such extension would be to consider such a model in the context of an open economy, with added Keynesian features such as a fraction of agents whose consumption is equal to their labour income.

The new-classical approach has been attractive to many macroeconomists over the past 15 years, and in large part this attraction stems from the internal consistency of the framework. Recently, progress on improving the quantitative performance has made this class of models even more attractive. As King (1991) notes, "...one cannot fail to be impressed by the general ability of models of nominal rigidities to mimic important aspects of the postwar U.S. relationship between money and the business cycle." The progress in making these models resemble real world experience has generated optimism that this class of models promises to become a relevant policy tool in the near future. It remains possible, however, that an approach that allows no role for price rigidities will be unable to explain all of the characteristics of the business cycle, and of the role of nominal shocks in explaining that cycle. The new-Keynesian and new-classical research agendas may yet converge on a consensus model that includes microfoundations-based price rigidities. Public policy would then gain a powerful new tool.

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